

“Hot Plasma Region by MHD Shock Formation in BH Accretion”

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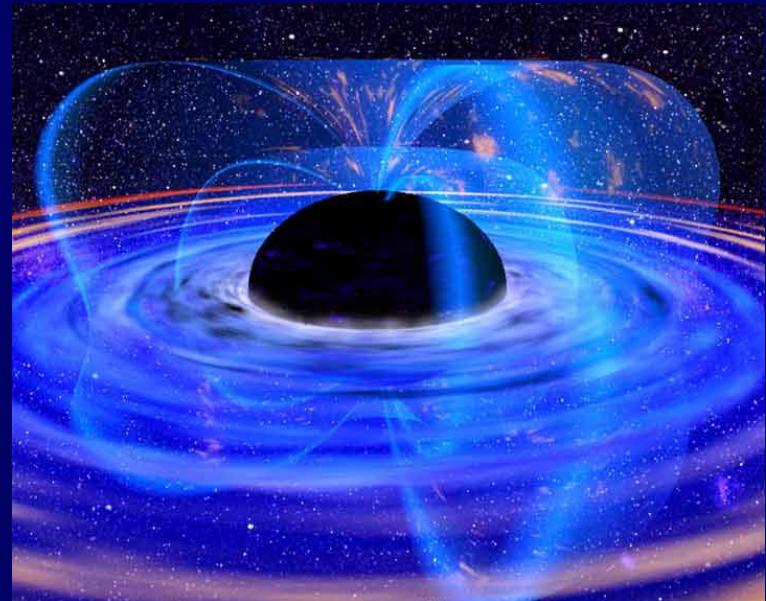
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Darrell Rilett

(Montana State)



http://www.esa.int/esaCP/ESAL2MZK0TC_index_0.html

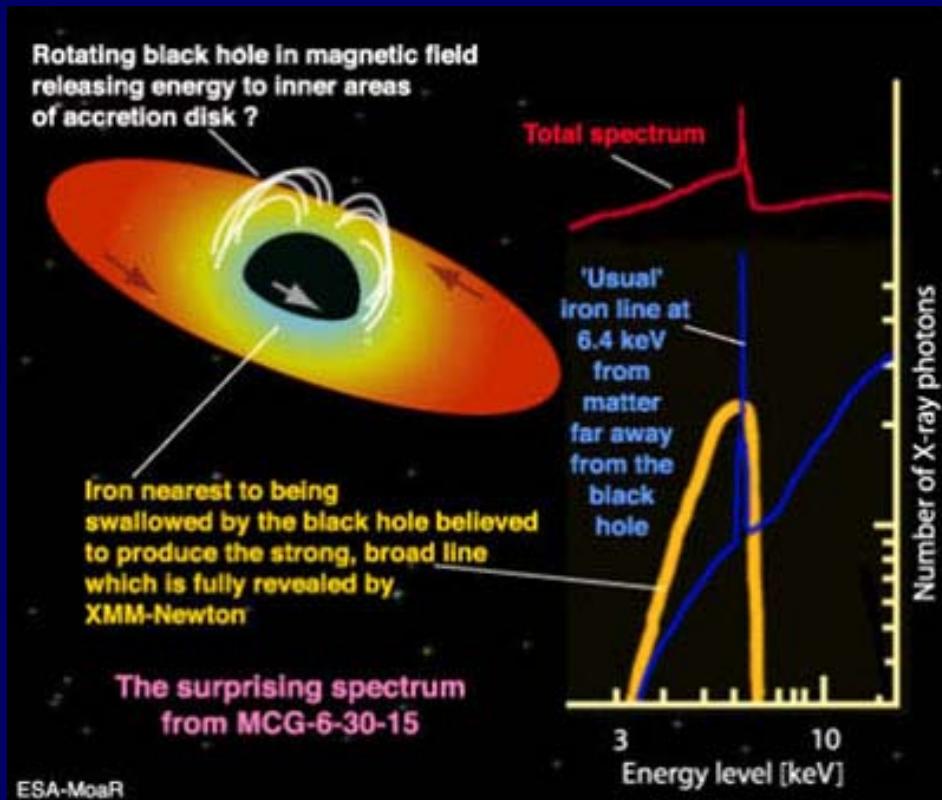
Outline

- Motivation
- Trans-magnetosonic Accreting Flows
- Adiabatic GRMHD Shock Formation
- Summary & Future Works

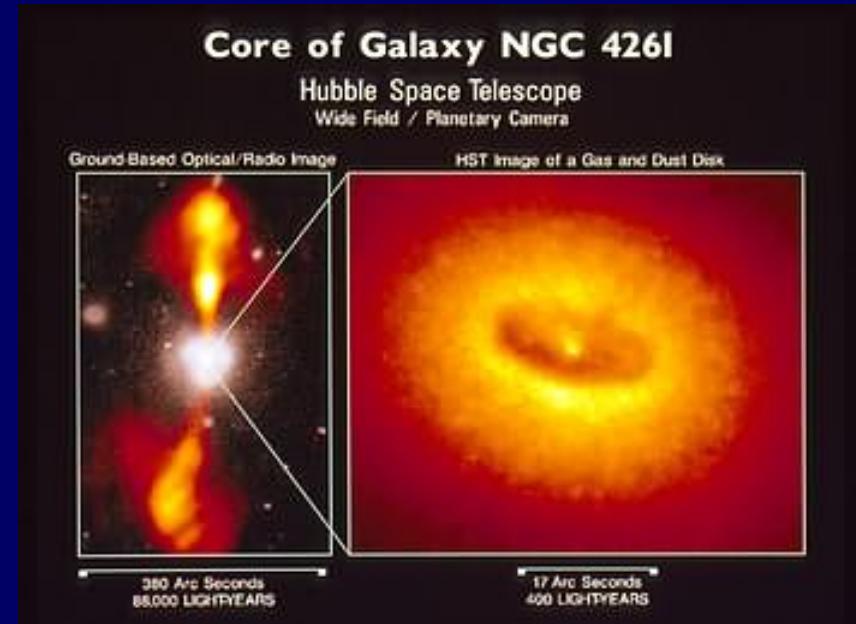
Motivation (1) ~ Observations

- Accretion Disk + Jets/Winds
- Global Magnetic Field (BH Magnetosphere)

Fe Line

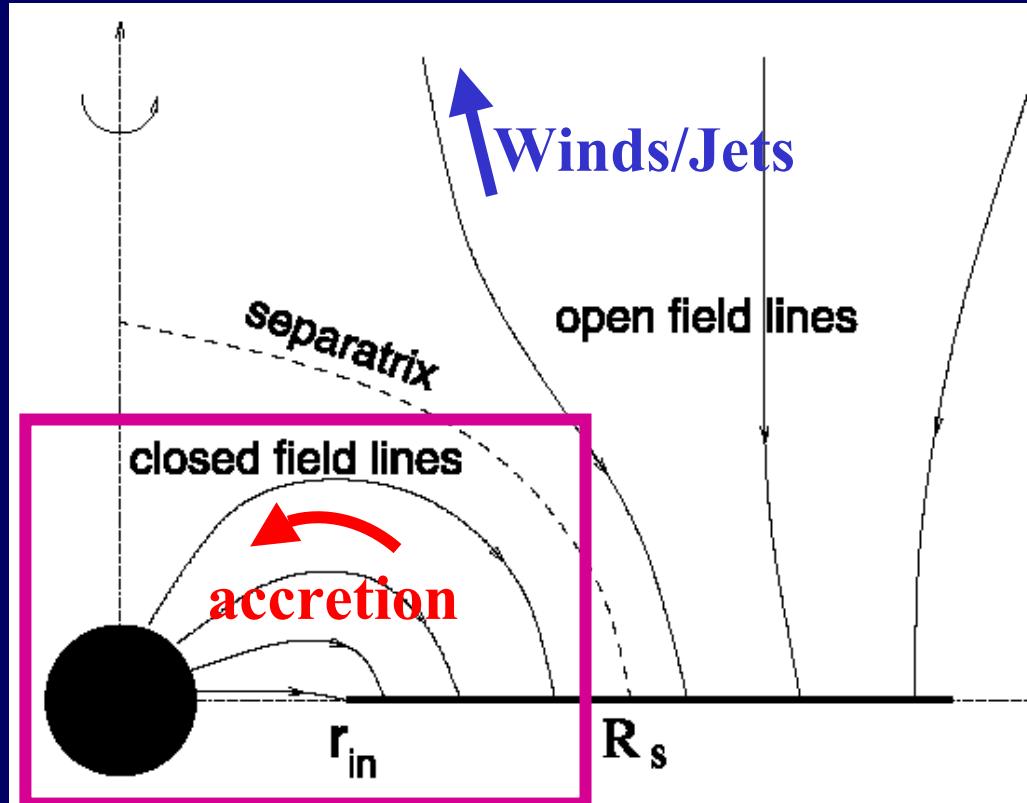


Collimated Jets



http://hubblesite.org/gallery/album/entire_collection/pr1992027b

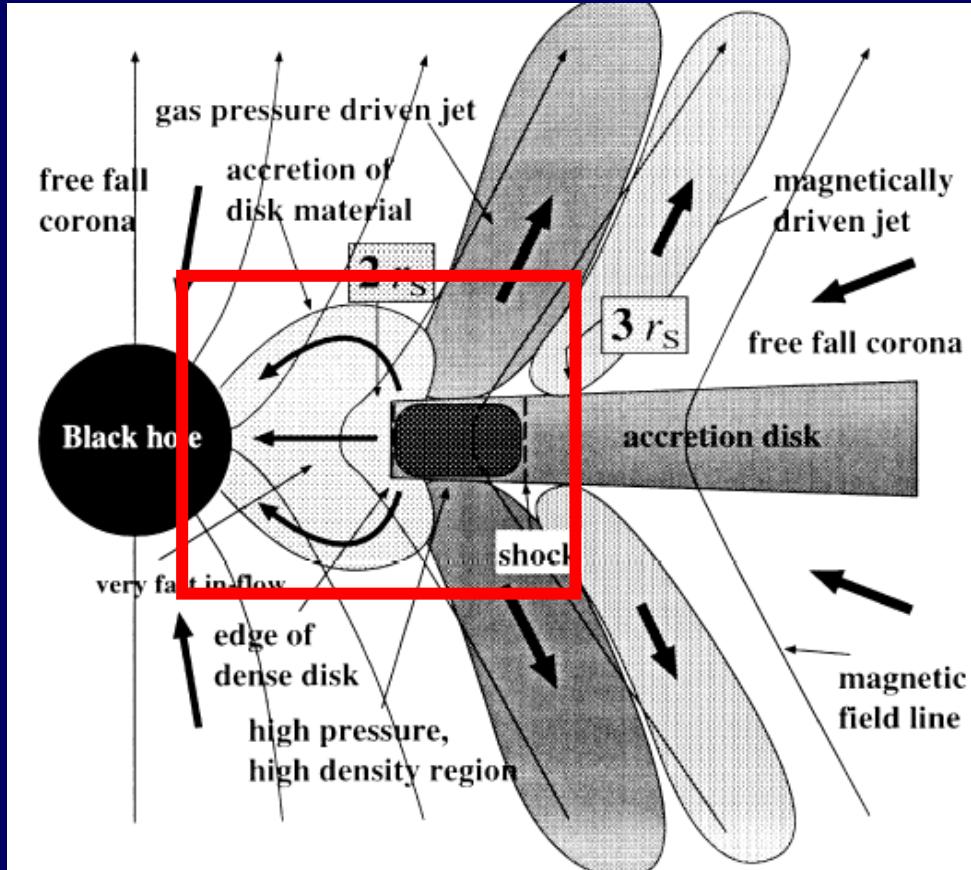
Motivation (2) ~ Theory



Uzdensky (2005), ApJ, 620, 889

Steady-state, magnetically-coupled configuration

Motivation (3) ~ Theory



Koide, Shibata, & Kudoh (1999), ApJ, 522, 727

(See also Hirose et al. 2004, ApJ, 606, 1083;
McKinney & Gammie 2004, ApJ, 611, 977)

Trans-magnetosonic Accreting Flows

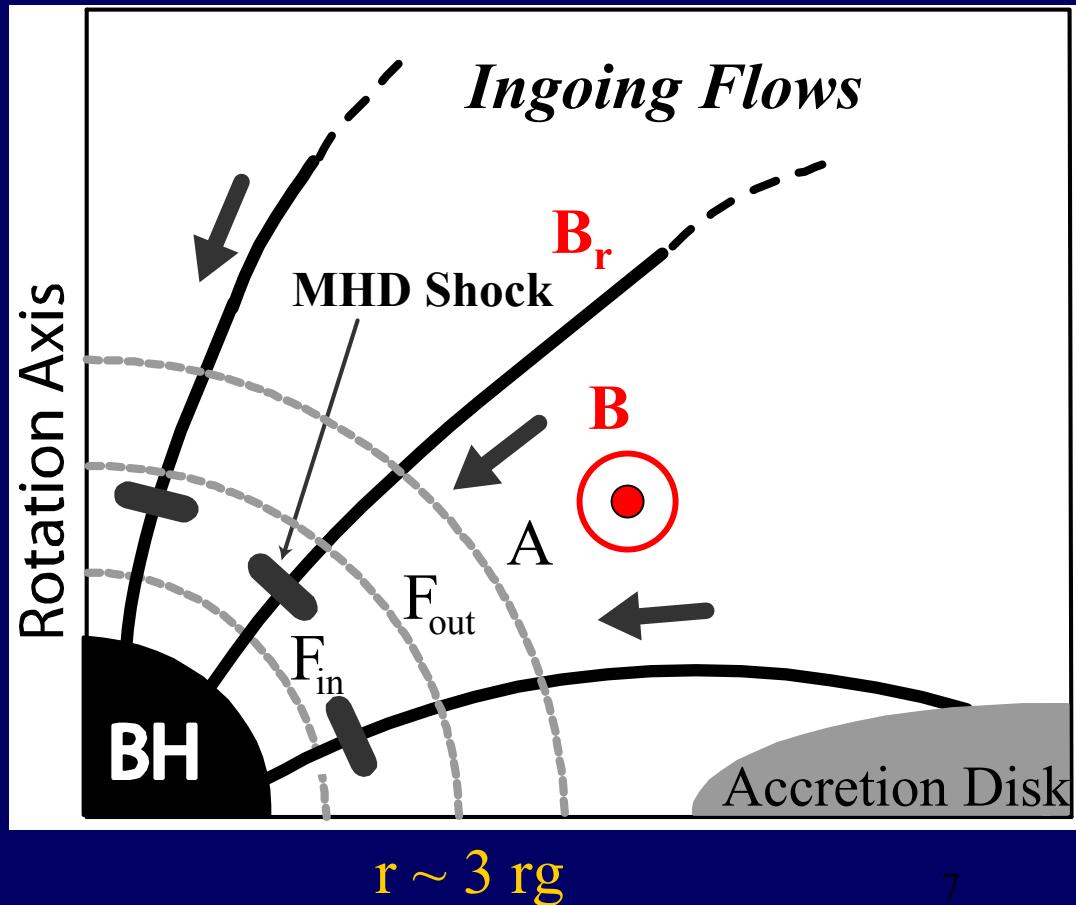
- Steady-state, axially symmetric GRMHD model (Kerr)
- Global Magnetic Field (BH Magnetosphere)
(plasma frozen-in to poloidal field + toroidal motion)
- Trans-magnetosonic solutions
(Slow point → Alfvén point → Fast point → Horizon)
- Five field-aligned conserved quantities + geometry
($E, L, \underline{L}_F, \underline{S}, S; a, \underline{a}$)

$$E = \mu u_t - \frac{B_\phi \Omega_F}{4\pi\eta} \quad L = -\mu u_\phi - \frac{B_\phi}{4\pi\eta}$$

Adiabatic MHD Shock Formation (1)

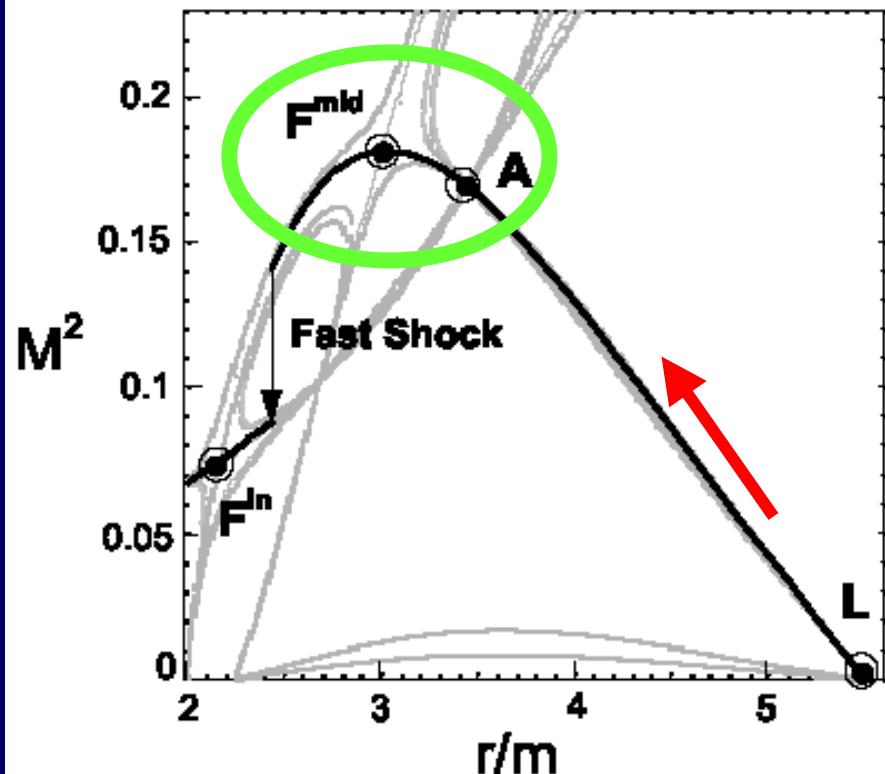
*We are interested in regions close to the horizon
(i.e., $r \sim 2-4 \text{ rg}$)*

- Plasma source
(e.g., accretion disk,
corona, pair creation
...etc.)
- Radial poloidal field
- Rotation of toroidal
magnetic field (B_r , B_θ)
- Standing MHD shock
(Adiabatic condition)

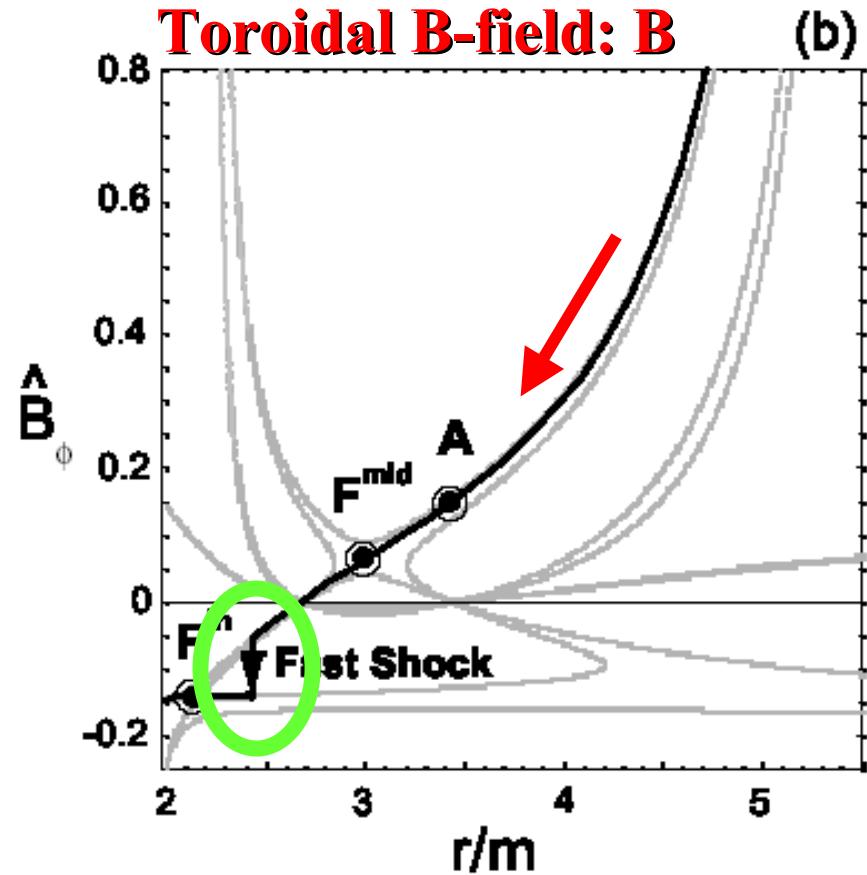


Adiabatic MHD Shock Formation (2)

(Poloidal) Mach Number: M (a)



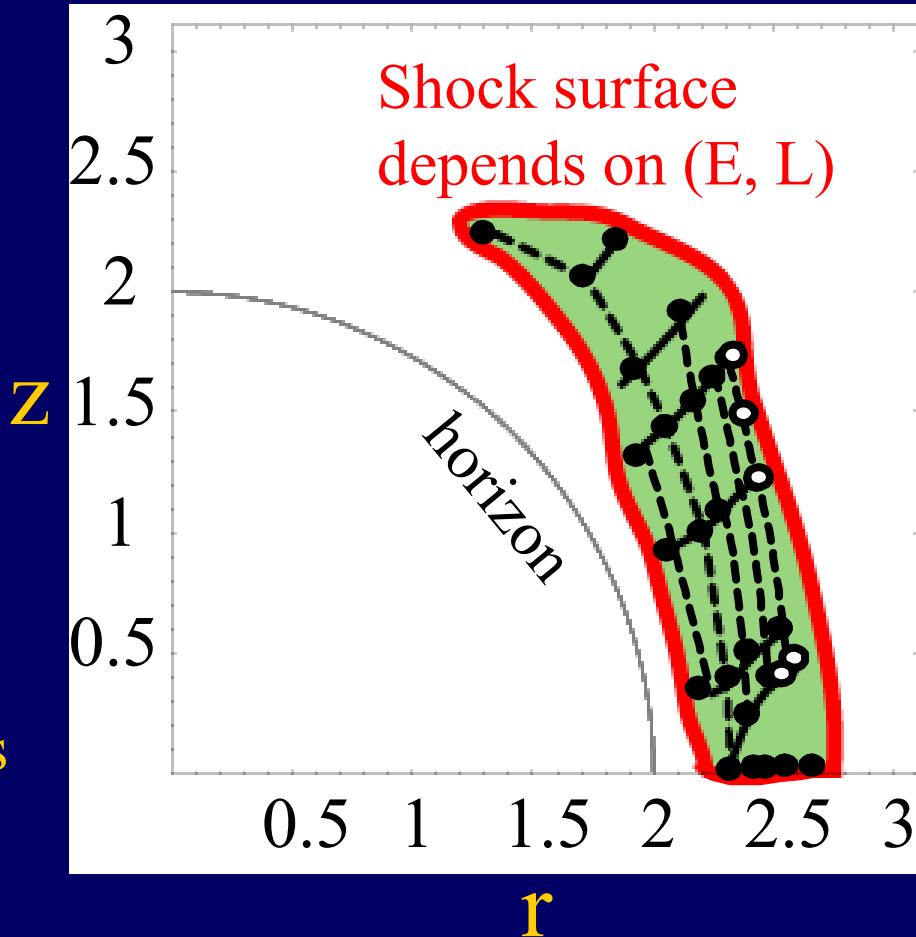
Toroidal B-field: B (b)



- Plasma “decelerates” → shock can develop
- Fast MHD shocks → $|B|$ increases

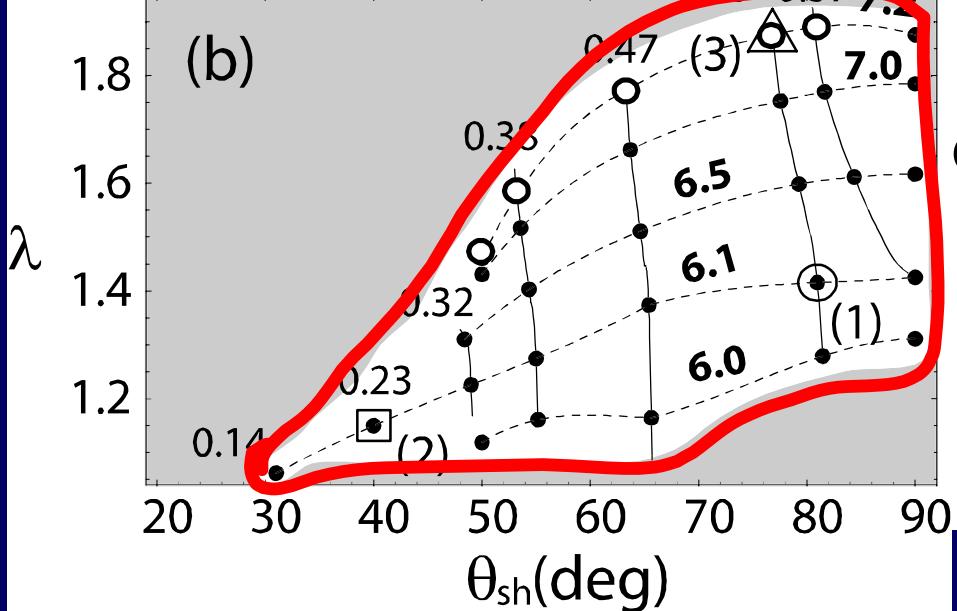
Adiabatic MHD Shock Formation (3)

- Shock front near horizon (e.g., $r \sim 2-3$ rg)
- Low/High-latitude MHD shock ($a=0$ & $a=0.5$ BH)
- Shock allowed region constrained by parameters

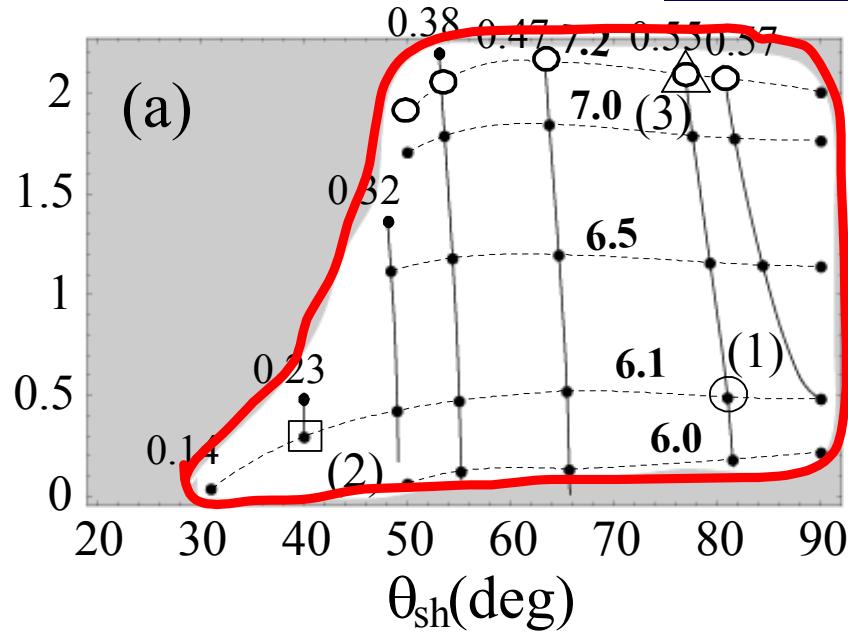


Adiabatic MHD Shock Formation (4)

Compression ratio



Downstream Temperature



Fukumura, Takahashi, & Tsuruta (2006),
in preparation

Highly heated downstream plasma ($\gamma = kT/mc^2 \sim 2$) in the vicinity of the event horizon (e.g., $r \sim 2-3$ rg)

Summary & Future Works

- Low/High-latitude MHD shock formation in the vicinity of the horizon (e.g., $r \sim 2\text{-}3$ rg)
- Hot shocked plasma region above the disk (e.g., $T \sim 10^{9\text{-}12}$ K)
→ Powerful radiation site (local X-ray source)
- Illumination of an accretion disk (can form steep emissivity law?)
- Partly responsible for the base of winds/outflowing particles

- Emergent shock-driven X-ray spectra (thermal + nonthermal)
- Isothermal (radiative) MHD shocks in accretion/winds
(e.g., Fabian et al. 2003, 2006)